Environmental Services Scheme

An overview of the environmental service indices developed for use in the NSW Environmental Services Scheme

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1. General Principles

One of the essential conditions for potential markets for environmental services is a system for measuring the environmental value of changes in land use or management. If possible, the impact of such changes should be measured directly, e.g. by estimating the quantity of an increased carbon sink created through tree planting using standard carbon accounting techniques. In many cases it is not possible to measure the value of land use changes in contributing to additional environmental service levels through direct means. Where salinity benefits result from tree planting throughout a catchment, the impacts on stream water quality are the product of a large number of inputs from specific sites, and the individual contributions will mostly be difficult or even impossible to measure directly. In other instances the benefits may not be evident until long after the original action, as in the case of improving habitat for biodiversity through recreating vegetation systems. In these cases it is necessary to determine suitable parameters that can be used as a satisfactory indicator of these environmental services (this is sometimes referred to as a surrogate measure).

Suitable parameters should have the following features. They should:

- Provide a measure at a property level that can be related to the environmental service at a catchment or regional scale
- Be simple to understand
- Be accurate, cheap to measure and reliable to use.

They should also be capable of being combined into a single environmental benefits index (EBI) where more than one environmental service is a priority. This requires that each parameter can be expressed in a form which allows combination with other parameters, i.e. the units must have a similar basis with scores out of a common maximum value such as 10 or 100.

2. Environmental Service Categories

The following environmental services were selected for evaluation under the Environmental Services Scheme (ESS):

- Carbon sequestration
- Salinity mitigation
- Acid sulfate soil mitigation
- Biodiversity enhancement
- Soil retention
- Water quality improvement.

These services were chosen because they include the major categories of environmental services of value to the community generally, i.e. air quality, water quality, soil quality and vegetation quality.

Another essential criterion was that it was feasible that acceptable methods for their measurement could be developed within the timeframe of the project. It was also important that the selected services could be clearly linked with specific land use changes that landholders could readily implement and incorporate into a whole property plan.

Environmental service indices were developed for each of the six services by teams of scientific experts from various agencies and other institutions. Where possible, existing indices of each service were adopted. If models already existed that provided an adequate way of estimating each index, then these were used. In other cases, new models were developed.

3. Toolkits Developed to Measure Environmental Service Indices

Detailed technical accounts of each toolkit and index are available (see http://www.dlwc.nsw.gov.au/care/es_scheme.html and http://www.forest.nsw.gov.au/env_services/ess/default.asp).

This document is an abbreviated account of their structure and application. The objective in developing these toolkits was to allow trained staff to use them either in the office as a desktop tool or in the field during discussions with landholders about alternative scenarios for land use changes on their property. For some services it has been possible to develop simple toolkits which allow non-technical users to estimate the level of environmental services resulting from proposed land use change (e.g. the Carbon Sequestration Toolkit at the State forests site above). In addition, we plan to produce easy to read accounts of each toolkit to familiarise landholders and others with the concepts which are involved.

Carbon Sequestration

The Carbon Sequestration Predictor provides a tool for predicting likely changes in both biomass and soil carbon associated with a number of land use changes at the property scale. The principal focus of the current version of the model is on changes from herbaceous (cropping, pasture) to woody vegetation (commercial and environmental tree plantings) in inland regions (<800 mm year -1 rainfall) contributing to dryland salinity in NSW. The tool provides predictions of changes in carbon stocks (biomass, soil and total carbon). A table presents predicted changes in carbon stocks expressed as tonnes of carbon per hectare, 10 years after the land use change. Many land use changes take a considerably longer time to reach a new quasi-equilibrium carbon storage level. A graph of predicted carbon changes over 40 years is also provided to indicate the longer-term benefits.

The Carbon Sequestration Predictor is easy to use. Inputs required are the current land use, the proposed land use, the rainfall, soil type and a soil-landscape modifier (accounting for factors such as salinity, waterlogging, erosion, etc). Outputs have been referenced against limited data collected by State Forests of NSW, Department of Infrastructure, Planning and Natural Resources, NSW Department of Agriculture and the CRC for Greenhouse Accounting. As additional data become available these will be incorporated to provide improved predictions.

Predictions of carbon sequestration for areas with > 800 mm year-1 rainfall are indicative only. It is recommended that commercial plantation carbon sequestration models are used for these areas. Predictions of carbon sequestration do not imply that such carbon complies with the Kyoto Protocol on greenhouse gas reductions.

The carbon sequestration predictor is available as a downloadable file at http://www.forest.nsw.gov.au/env_services/ess/default.asp.

Salinity Mitigation Benefit

The contribution of a particular property to increased stream salinity loads is a complex process which is affected by local and regional hydrological considerations. The approach used to estimate salinity mitigation benefits arising from land use change employs models of salt and water flow in the landscape. The modelling methodology used to determine the potential impacts of the different land use changes on catchment salt and water exports is a simplification of the CATSALT v1.5 methodology. Mean annual streamflow and salt loads, calculated for the reference period 1975 to 1995, are distributed across their contributing area based on the major factors affecting hydrological behaviour such as land use, topographic position, salt storage and discharge potential (the last two parameters defining salt hazard).

Every unique combination of land use, topographic index and salinity hazard is defined in terms of its contribution to total water and salt yields. With these values known, it is then possible to predict the consequence of a land use anywhere in the catchment on flow and salt yield.

The salinity benefits index model is used in conjunction with a spatially based platform called the Land Use Options Simulator (LUOS). LUOS is a GIS based tool designed for:

- Recording, updating and correcting spatial information such as land use
- Using decision rules and models to locate areas for potential land use change
- Quantifying the effects of land use change using scientific models
- Comparing land use options for the basis of property agreements and environmental credit allocation.

The tool is designed for use within the office, or to be taken on site-visits using a laptop. It is fully scalable and capable of switching scale or area-of-interest, so individual properties or whole catchments can be assessed. It has been developed to require no previous GIS experience, and to minimise training time for operators.

The salinity benefits model estimates the impact of land use changes at a site on the average annual streamflow and salt load exported from the catchment in which the site is located. By calculating the ratio of salt load to streamflow for existing conditions and for post-land use change conditions, the model calculates a raw Salinity Benefits Index (SBI) value. The local catchment outlet is the reference point for this calculation. The SBI value is expressed as a percentage change in stream salinity. To allow for comparison between catchments (which may have significantly different stream salinities), the change is expressed as a percentage of the current in-stream salinity, rather than as an absolute value in tonnes/megalitre. The percentage change to in-stream salinity is multiplied by -1 so that a drop in in-stream salinity gives a positive (beneficial) value, and an increase gives a negative (detrimental) value. The results may be further scaled to give numbers that generally lie in a reasonable range (say, normally less than 10).

It may be seen from this description that the value of the raw SBI may be positive or negative, depending on the relative magnitudes of the two terms, In-streamSalinity current_landuse and In-streamSalinity future_landuse. For example, the value of the term for future land use conditions may be greater than the value for current land use if the land use change induces an estimated reduction in streamflow that is disproportionately greater than the reduction in salt load. In this case the raw SBI will be negative.

The magnitude of the raw SBI is affected by the size of the land use change at a site relative to the size of the catchment at the reference point. A given land use change at a site will have a greater percentage impact on the streamflows and salt load exports from a small catchment than from a large one. Amongst other things, this means that raw SBI values calculated at different reference points are not comparable (they may be reasonably comparable where catchments at each reference point are of about the same areas, but not where the catchment areas differ markedly). In order to allow for comparisons to be made between sites which are located within the same valley, or between sites located in different valleys (State scale), the raw SBI can be expressed in relation to the aggregates of stream flow and salinity loads at these different scales. Care needs to be exercised in interpreting indices derived at these different reference points, as both the magnitude and the sign of the index can change.

Coastal Acid Sulfate Soil (ASS) Mitigation

Management and land use changes which may mitigate the impact of coastal acid sulfate soils can follow two broad strategies depending on the landscape context:

1. Maintaining a low watertable and minimising the amount of rainfall which infiltrates into the soil profile thus displacing acid ground water into drains and waterways;
2. Maintaining a high watertable to minimise the drying/wetting cycles of the sulfidic or sulfuric acid layer in the soil profile. The selection of specific strategies presents differing issues for measuring the impacts of land use changes.

A measure of the impact of ASS management strategies on the surrounding environment can be obtained by estimating the total export of acid or ASS products off-farm as an indication of the net contribution of a specific property to pH reductions in surrounding waterways. The potential for a specific site to export acidity has been modelled in only limited instances and is known to be a complex issue affected by specific characteristics of the ASS at the site, as well as previous land use practices. For this reason, during the ESS selection process a toolkit was developed by a panel of technical experts using rankings of the relative impacts of land use and land use change in specific locations. The land use changes are ranked in a numerical scale of values or indices. The index values reflect the relative long-term beneficial environmental impact of the land use change options. The specific ASS index values can be re-scaled as required to make them consistent with an overall combined EBI.

The toolkit incorporates into the index estimation a range of environmental factors, such as the sensitivity of receiving waters and the severity and variability of ASS conditions. It also includes a measure of the magnitude of ASS remediation /engineering modification proposed, such as area or length of drains to be modified, or number/scale of floodgate modifications.

Following the selection of sites for the ESS project, a climatically standardised water balance model (ASSESS) was developed to estimate annual acid export from an ASS basin. The change in acid export is derived from the net improvement from baseline conditions to those which apply following the implementation of remedial works. An appropriate monitoring program will be established on each site to evaluate the accuracy of the model as a tool for estimating an ASS index.

Biodiversity Benefits

A prototype toolkit has been developed to assess the biodiversity benefits (and disbenefits) likely to result from land use change. The toolkit builds upon the Habitat Hectares methodology developed by the Department of Natural Resources and Environment (Victoria) and applied to the Victorian BushTender Trial. The toolkit also incorporates recommendations from a Technical Advisory Group, as well as results generated by a Vegetation Condition Expert Panel (for a full account see http://www.dlwc.nsw.gov.au/care/es_scheme.html).

The toolkit has been designed to achieve three goals:

- Quantify the current biodiversity value of a site
- Estimate the magnitude and direction of change in biodiversity value as a result of land use change
- Incorporate these current and potential values into an Index.

The biodiversity benefits index is calculated on the basis of three surrogate measures of biodiversity:

Vegetation Condition, Conservation Significance and Landscape Context.

Vegetation Condition – this is important for estimating the current biodiversity value at the site-scale. It is defined as the degree to which the current vegetation differs from a Vegetation Condition Benchmark representing the average characteristics of the mature native vegetation type/s predicted to have occupied the site prior to agricultural development. It describes the degree to which critical habitat components and other resources needed by indigenous plants and animals are present at the site. Predicted changes to vegetation condition due to land use change are also estimated and included in the index.

Conservation Significance – this is important for estimating the biodiversity value of a site in a regional context. Some sites may represent elements of biodiversity that are common in the landscape, others may represent elements that are now rare. Conservation Significance recognises the amount of each element now in the landscape compared with a time prior to agricultural development, as well as the likelihood of the element persisting. Predicted changes to conservation significance are also included in the index.

Landscape Context – this recognises that the biodiversity value of an area of vegetation will vary depending on where the site is located in the wider landscape. Small sites surrounded by a "sea" of agriculture will have poor landscape context compared with sites close to large semi-natural areas.

The biodiversity index, is calculated as:

(CS t0 + LC) VC t0 / c *the Biodiversity Significance Score*
×
((VC tn - VC t0) + (CS tn - CS t0)) / d *the Land Use Change Impact Score*

Where:

CS t0	=	Current Conservation Significance, that is, prior to land use change,
CS tn	=	Potential Conservation Significance, i.e. after land use change,
LC	=	Landscape Context,
VC t0	=	Current Vegetation Condition, that is, prior to land use change,
VC tn	=	Potential Vegetation Condition, i.e. after land use change and an agreed period of time,
c, d	=	constants.

The biodiversity index is calculated as a change in benefits per hectare during the 10 year period following land use change. Application of the index to the ESS sites will require that vegetation benchmarks are developed for each relevant vegetation type. This will be carried out using a rapid expert panel based system, pending more comprehensive data becoming available. A spreadsheet version of the toolkit has been developed and is being refined through use in assessing the ESS sites.

Soil Retention

Selecting a suitable measure of soil management benefits is complicated by a number of factors. Improved management of soil has many benefits, including improved soil fertility, water infiltration and retention, as well as the control of erosion. Most of these changes will generate benefits which can be captured by the landholder directly, e.g. through increased productivity. For the ESS it was considered preferable to select a service which produces mainly external impacts, such as reduced sediment transport off-farm.

A model to predict the changes in off-farm export of sediment was developed based primarily on a partitioning among:

a) gully erosion and soil erosion by sheet and rill erosion;
b) sediment generation and sediment delivery beyond the farm; and
c) coarse and fine fractions.

The last is particularly important for input to the water quality (nutrient retention) index that requires information about the generation and delivery of fine sediments that contain the majority of attached nutrients.

Appropriate equations were defined that described each of the above components. The toolkit made use of available software such as the SOILOSS program (Rosewell, 1993) in order to explain sheet and rill erosion. Future modification of this program may be necessary so that it can be incorporated into the Land Use Options Simulator.

Water Quality Benefits (Nutrient Retention)

The impact of land use or land management on water quality in adjoining streams is a complex result of a wide range of factors including geomorphology, vegetation ecosystems present, presence or absence of introduced and native animals, upstream developments and activities and the previous history of the site. Water quality benefits, in the context of this project, were regarded as the level of undesirable nutrients such as nitrogen and phosphorus leaving the property. It was not considered practicable to directly demonstrate improvements to water quality resulting from reduced nutrient exports at a property level as this would involve the continuous measurement of water flows and quality at the site.

The ESS Nutrient Retention Toolkit allows the indirect estimation of changes in nutrient retention at a property scale based on previously established nutrient (nitrogen and phosphorus) generation rates under different land use systems. These base generation rates are adjusted for variations in rainfall and soil type and multiplied by the area in hectares. This score represents improvements in nutrient export for specific land use changes on any property within the particular combination of rainfall and soil type. A second set of modifying factors is applied to enable finer discrimination amongst properties differing in:

- management practices (stocking rate, ground cover)
- topography
- proximity to drainage lines, as well as
- the existence of structures or features which may act as barriers to the transport of nutrients from the land to adjacent streams.

The toolkit expresses an index of nutrient retention in kilograms of nutrients (N + P) retained per year as a result of the land use changes on the area in question.
Further development of the nutrient retention toolkit incorporates modelled nutrient transport functions, derived from the soil retention toolkit, to estimate the effects of site characteristics on nutrient export from the site.

Subsequent to the original development of the nutrient retention toolkit, it has been integrated with the soil retention toolkit to take advantage of the sediment generation and transport models. The combined toolkit provides a means of estimating both soil and nutrient retention benefits form a given land use change.

4. Further Refinements to Indices and Toolkits

Following the development of the toolkits for use in the ESS, further refinements are planned. The aim of these refinements in general, is to improve the simplicity and accuracy of the indices, and to ensure consistency throughout the range of landholdings over which the indices are applied. Changes which require the acquisition of new data e.g. on soil carbon in cropping systems, or significant new conceptual work (the inclusion of aquatic biodiversity) will be undertaken as time and resources allow.

Further changes have been carried out to the underlying models for the salinity benefits index and to the biodiversity index. For example, changes to the salinity benefits index now enable the modelled changes in salt load and water flow to be calculated in relation to the impacts at various reference points e.g. at the end of the valley as well as the local catchment defined by the nearest gauging station. In the case of the biodiversity toolkit, the assessment of conservation significance of the specific vegetation types has been simplified to use a set of standard categories to allocate a score for this parameter.

LUOS

Improved linkages of the toolkits with Version 2 of the LUOS are also being carried out. The first version of LUOS had been developed in ArcView, however, it was quickly realised that the cost of the software needed would limit its widespread adoption.

Consequently, version 2 of the LUOS is being developed in The Invisible Modelling Environment (TIME), which is a system for developing and deploying environmental models, developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH). TIME uses Microsoft's .NET platform, which allows the integration of software written in a variety of languages. TIME handles data in a number of formats, including: point, line and polygon coverages; grids; time-series; and node-link networks.

Much of the basic GIS functionality required is available in TIME. The LUOS developers have been concentrating on creating an 'ArcView' style user interface and data models, and it is expected that this interface will be useful for deploying lower end, more user friendly GIS applications.

The LUOS modelling components are either biophysical or economic. A social model component is not included, since the purpose of the tool is to assist in property-scale planning, where the individual ultimately drives decisions.

The biophysical components permit quantitative assessments of the impacts of land use change / management on various environmental services. These assessments are reported as indices, which enable different options on a property (or from a wider catchment perspective, between properties) to be compared.

The indices can also be combined and reported as a composite environmental benefits index (EBI). The individual services can all be given equal importance in the EBI (as was the case in the ESS), or weighted to reflect their relative priorities within the specific catchment.

The economic model is currently designed to evaluate the costs of making a land use change, as well as the value of the foregone use of the land. Costs might include land preparation, planting (e.g. trees), fencing and ongoing maintenance. As more data are available, the net economic impacts of land use changes on farm business performance will be incorporated into the models.

The new environment could eventually support a fully integrated spatial data system, combined with the various modules for calculating each of the indices, as well as an integrated EBI. Initially, the LUOS V.2 will provide spatial data to drive the current stand-alone Excel workbooks used to calculate the indices. LUOS V.2 will also generate reports on a combined EBI in addition to each of the individual indices. The LUOS is planned to be available as a CD incorporating the various toolkits for general use.

5. Comparison of the Indices

A comparison of the key characteristics of the individual environmental indices is set out below (Table 1). The comparison highlights areas for further development of the indices. Development of the indices will be assisted by data collected during the biophysical monitoring program being carried out on the sites selected for inclusion in the ESS project.

Table 1. Characteristics of Environmental Indices under the ESS project

INDEX	UNIT	TIME SCALE	LUC RANGE
Carbon sequestration	Tonnes of carbon per hectare for LUC	10 years from implementation – can extend to 40 years	ESS approved categories only
Salinity benefits	% change in stream salinity for whole area of LUCs combined	Assumes a "change of state" to a new hydrological equilibrium following land use change	ESS approved categories only – other LUC can be coded into model
Biodiversity benefits	Change in habitat value for LUC relative to benchmark per hectare	10 years from implementation – can be extended to any interval	ESS approved categories – but can also be applied to any changes which can compared with benchmarks
ASS mitigation benefits	Ranking compared with alternative measures for whole area of each LUC	Assumes "change of state" following land use change	ESS approved categories only
Soil Retention	Tonnes of sediment retained for area of each LUC per hectare per year	Assumes "change of state" following land use change	ESS approved categories – plus other cropping –related practices
Nutrient Retention	Kilograms of N+P retained for area of each LUC per hectare per year	Assumes "change of state" following land use change	ESS approved categories only

The Environmental Services Scheme is a collaborative project of the NSW Government including staff from the NSW Department of Infrastructure, Planning and Natural Resources, State Forests of NSW and NSW Agriculture.

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